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Effects of changing trade structure and technical characteristics of the manufacturing sector on energy intensity in Ghana

Philip K. Adom [a,*], Paul Adjei Kwakwa [b]

[a] Department of Banking and Finance, University of Professional Studies, Accra-Ghana
[b] Department of Business Economics, Presbyterian University College Ghana, Akropong Campus, P.O. Box 393, Akropong-Akuapem, Eastern Region, Ghana

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ABSTRACT

This study examined the effects of changing trade structure and changing technical characteristics of the manufacturing sector alongside the effects of foreign direct investment and urbanization on energy intensity in Ghana. In order to produce a result that is not biased towards non-rejection, the Zivot–Andrews unit root test with structural break was used. The study applied the Phillip–Hansen, Park, and Stock–Watson cointegration models, which are more robust to serial correlation and exogeneity problems. Preliminary findings showed evidence of cointegration. The study concludes that the changing technical characteristics of the manufacturing sector after the reform and changing production mix in favor of less energy intensive improved energy efficiency. However, energy consumption via exports which outweighed the energy saving via imports of capital goods after the reform in 1983 worsened energy efficiency. Growing urbanization significantly increases energy intensity. In all, technological diffusion via trade exerts significant influence on energy intensity than technological diffusion via foreign direct investment. These results are robust to the Cholesky variance decomposition analysis.

Contents

1. Introduction

Energy consumption is crucial to the sustainable development of countries. However, when not used efficiently, the consequences can be darned enormous for any economy, which includes threatening the sustainable development of the economy, energy

* Corresponding author. Tel.: +233 246763661.
E-mail addresses: adomonline@yahoo.co.uk (P.K. Adom), pauladkwa@yahoo.com (P.A. Kwakwa).

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security and worsening the environmental conditions. Achieving energy efficiency is thus, equally important as achieving price stability in an economy. Promoting energy efficiency has many potential benefits which include promoting market competitiveness, saving energy cost, creating a low carbon economy and improving clean energy access. Closely related to the energy efficiency concept is the energy intensity ratio, which shows how many of oil equivalent is required per unit of output. Conventionally this ratio has been used to measure energy efficiency in the literature [1–7].

Prior to the 1970 world oil price shock, increasing energy consumption was highly emphasized and promoted in every economy due to the identified strong linkage between energy and sustainable development. However, the 1970 oil price shock along with the events that unfolded afterwards (i.e. increased urbanization, population, industrialization, and environmental crisis) awaken the need to pursue energy conservation policies more vigorously. Thus, instead of merely promoting energy consumption, emphasis was now placed on how to use energy efficiently. After the oil price shock in 1970, energy intensity declined in many developed countries [8,9], but has increased substantially over the last three decades in developing countries. In Africa, energy intensity is high largely due to the extractive nature of industries, which are more energy intensive.

In Ghana, the consciousness of energy efficiency grew from 1973 to 1979 during which time Nigeria placed an oil embargo on the country. Historical evidence reveals that the levels of energy intensity in the country were high in the early years of the 1970s. There was, however, a reversal in the trend as energy intensity decreased consistently, with the level of decline highly marked between 1981 and 1983. The cause of this was a corollary of growth recession and energy efficiency promotion measures implemented. However, the trend in energy intensity changed drastically after the reform. Consistently, the rate of energy utilization increased. Since that period, various initiatives have been implemented to facilitate the efficient use of energy, in the country. These include establishing appropriate pricing regime for energy services that would encourage domestic and industrial customers to manage their energy consumption voluntarily; developing and implementing market transformation aimed at removing market barriers that hinder the mass adoption and use of energy efficient conservation, and promoting the utilization of more efficient charcoal production and end-use fuel wood combustion technologies (i.e. Cooking stoves), via training, fiscal incentives, and regulation. However, the levels of energy intensity still remain high in the country. Understanding the causes of the underlying trends in energy intensity is both an essential step to energy conservation, and a rough basis for projecting energy consumption requirements and the associated environmental ramifications. The main objective of this study is, thus, to determine the factors that explain the historical trends in energy intensity in Ghana using time series data covering the period 1971–2011. Preferably sectoral analyses would have been much revealing. However, the present study is limited by data problems to do such analysis. As a result, this study focuses on the aggregate analysis of energy intensity and its' determinants in Ghana.

Various factors such as production technology, technological advances, urbanization, economic structure, energy price, investment, and structural effects have been extensively analyzed in the literature [3,10–12]. However, little is known in the literature about the effects of changing trade structure and changing technical characteristics of the manufacturing sector on energy intensity. Trade openness facilitates the transfer of technology and spurs competition among local firms. This facilitates energy efficiency in the local economy. However, whether trade openness will spur energy efficiency increases depends on the structure of trade. Also, expansion of manufacturing scale drives energy use in the country due to the high energy intensive nature of the sector. However, trade reforms that encourage the transfer of energy efficient technologies and ban the importation of energy inefficient technologies change the technical characteristic of the manufacturing sector. As a result, energy efficiency is promoted. In this study, the authors consider the effects of trade openness; manufacturing value-added, urbanization, and foreign direct investment in explaining energy intensity in Ghana. In order to capture the changing trade structure and the changing technical characteristics of the manufacturing sector a dummy for policy regime change, (where 1 is for periods after the reform and 0 for periods before the reform) is interacted with trade openness and manufacturing value added. These two interactive terms are included as additional regressors in the model to be estimated.

In the case of Ghana, the current study is novel as previous energy studies on Ghana have focused on modeling and forecasting electricity demand [4–7]; testing the energy conservation hypothesis [13–16] and examining the relationship between economic growth and carbon dioxide emissions [17]. Also, there is a dearth of research that investigates the determinants of energy intensity in Africa [18–21]. However, none of these studies captures the roles of changing trade structure and changing technical characteristics of the manufacturing sector as explicitly done in this study.

The rest of the paper is organized as follows; section two reviews relevant literature, section three describes the data and method used, section four explains and discusses the result of the study, and section five concludes and makes policy recommendations.

2. Literature review

At the Copenhagen conference on climate change in 2009, consensus was reached to support developing countries in employing energy-saving technologies. This is because these economies are known to contribute about 7% of the increase in global primary energy use between 2005 and 2030. Understanding the trends in energy intensity in these economies and the underlying driving factors proves to be imperative for achieving the desired outcomes for such initiatives. In the literature, several factors have been outlined to have significant impact on reducing an economy's energy intensity. The factors that have played out to be most prominent is technological diffusion driven by trade openness and foreign direct investment, and structural shifts in the economy away from more energy-intensive sectors to less energy-intensive sectors.

Trade openness results in the importation of capital and intermediate goods, which have technologies embedded in them. The importation of these capital goods coupled with the improved application methods, as a result of competition, creates productivity spillovers [22,23]. Also, FDI flows contribute to the existing level of knowledge via skills acquisition, labor training, and the introduction of alternative management practice and this help improve a country's energy efficiency [24,25] and [26] in [27]. Albeit, there is an agreement on the roles of FDI and trade in reducing energy intensity, their specific roles are not clear in the literature.

The important role of economic integration in reducing energy intensity is confirmed by Shi [28] and Zhang and Chen [29]. Also, other studies have confirmed FDI's role in increasing energy efficiency. Eskeland and Harrison [30] found that FDI reduces energy intensity in Cote d'Ivoire, Mexico and Venezuela. Similar result was found using data from China. Blackman and Wu [31] concluded that FDI increases China's energy efficiency via competition and demonstration effects. Mielnik and Goldemberg [32] also concluded based on an ordinary least square regression that FDI

reduces energy intensity. Luo [33] also found that FDI has a positive impact on total factor productivity. Hubler and Keller [20] argued that Luo's result may be spurious since the author failed to consider other influence of energy demand. In their work, the authors dealt with this problem by applying panel-estimation for a sample of 60 developing countries. They concluded that FDI and trade may reduce energy intensity by composition and technical effects. In a similar study, Hubler [11] found that FDI and trade openness are responsible for the reduction in energy intensity, in China.

However, in a study by Lai et al. [34], it was found that the technological spillover effects of FDI seem more important than those of trade. Fisher-Vabdeb et al. [12] concluded that FDI decrease energy intensity, but the effect of trade openness is indeterminate. Cole [35] argues that the impact of trade on energy intensity is country specific. Therefore, it can be positive or negative depending on whether the country is importing or exporting energy intensive products. Shen [36] confirms this in a study based on the input–output table. Shen [36] concluded that foreign trade increases energy efficiency and the energy saved by imports are more than the energy consumed by exports. The author further argues that the declining positive role of trade is due to the changing composition of trade (i.e. rising share of energy-intensive exports and the falling share of energy-intensive imports).

Other studies have established the importance of some other factors in reducing energy intensity. For instance, Cornillie and Fankhanser [37] found that energy prices and progress in enterprise restructuring are the two most important drivers for efficient energy use in 22 transition countries. Irawan et al. [38] found that wage, age, capital intensity and share of capital owned by the private sector have positive impact on energy intensity in the manufacturing sector of Indonesia. However, factors such as the size of the firm, labor productivity and technology intensity has negative influence on energy intensity. Garbaccio and Ho [39] examined energy intensity and the factors leading to it in 1987–1992. The study revealed that technology among sectors is the main reason for energy intensity decline. In South Africa, Inglesi-Lotz and Pouris [18] using a decomposition approach found that structural changes in the economy has a negative role in the increasing economy-wide energy efficiency whilst energy usage intensity contributed to decreasing trend of energy efficiency. Poumanyvong and Kaneko [40] studied how rising industrial activities affect energy intensity using a dataset from 1975 to 2005 on 99 countries. Their study found that the impact of the share of industrial activity in the economy on energy intensity is positive but statistically significant for only the low and middle income groups.

Lastly, the impact of urbanization on energy intensity has also been established. Sadorsky [41] examined the effects that urbanization, income, and industrialization have on energy intensity for a panel of 76 developing countries. Employing both dynamic and static panel models the author found that, in the long-run, urbanization is not a significant determinant of energy intensity in the static model but the effect is significant in the dynamic specifications and slightly larger than unity, indicating that urbanization worsens energy intensity.

In Ghana, studies on energy have focused on either testing the energy conservative hypothesis or estimating demand for energy. Studies by Adom [13], Kawkaw [14], Wolde-Rufael [15] concluded that economic growth leads to increase energy use. Adom and Bekoe [5], Adom et al. [4], and Adom and Bekoe [6] found that urbanization, income, and structural changes in the economy towards the industrial sector lead to increases in electricity consumption. However, improvements in industrial energy efficiency reduce electricity consumption. Adom [7] concluded that a structural shift of the economy away from the more energy intensive sector to less energy intensive sector reduces electricity usage.

The above review reveals the following key points. First, extant literature on the impact of external factors (FDI and trade openness), in sub-Saharan Africa, is scanty and biased towards developing countries in Asia. Secondly, there is no literature on Ghana regarding the determinants of energy intensity. This study thus, attempts to fill this gap in the literature by examining the role of economic integration, FDI, manufacturing value added and urbanization in explaining energy intensity trends, in Ghana.

3. Country snapshot

Trade openness is a surrogate measure for economic integration. The structure of trade in Ghana has evolved from restrictive trade to liberalized trade. The time plot of, degree of economic integration, (i.e. Trade openness) shows that prior to reform the degree of economic openness was low. Thus, as shown in Fig. 1C, the share of trade (imports+exports) as a share of gross domestic product declined steadily. This reflects the restrictive nature of trade policies in the country prior to the reform in 1983. For instance, export as a share of total trade slacked in part due to the uncompetitive nature of the sector driven by exchange rate controls. However, after the reform in 1983, attempts were made to change the structure of Ghana's trade. Specifically promotion of exports was highly emphasized. As a result, the local currency was devalued to spur competition; exports duties were removed and export licensing was abolished in 1990, tax rebates ranging from 20% to 50% was devised (this was determined by the volume of total production that was exported), and diversification of exports [43]. These trade reforms enhanced the performance of the export sector relative to the import sector after the reform in 1983. Thus, the share of energy intensive exports rose above the share of energy intensive imports. As shown in Fig. 1C, the share of trade in total gross domestic product shows a consistent rise after the reform albeit there was a reversal in the trend after 2000. Generally, however, trade was more biased towards the export sector. The changing structure of trade in the country after the reform implies that the effect of trade openness on energy intensity is dependent on energy consuming exports and energy saving imports.

After independence much effort was put in place, to catch up with other developed economies. Among the initiatives, there was a greater emphasis on promoting industrialization and import substituted products. The benefits of these attempts were felt in the early periods. For instance, the share of manufacturing output in total industry output grew from 10% in 1960 to 14% in 1970. Between the periods from 1960 to 1970, growth rate of the manufacturing sector was 13%. Also, total employment in the manufacturing sector increased by 90% [43]. As shown in the Fig. 1D, the performance of the manufacturing sector was high in 1975. However, the performance of the sector begun to slack with the severity of the problem highly marked between 1980 and 1983. The profile of the manufacturing sector prior to reform in 1983 was characterized by obsolete machinery; poor quality products; low value added and, low contributions to GDP growth. During the reform in 1983 attempts were made to restructure the sector for economic growth. Particularly to promote importation of essential capital goods, import duties and trade taxes were reduced. According to the World Bank, capital goods constituted 43% of total imports after 1990s [43]. This trade policy alongside other auxiliary initiatives enhanced technological transfer and also improved efficiency and quality of products of local products after the reform. Statistics shows that the performance of the manufacturing sector improved. For instance, the real annual growth rate of manufacturing value added rose sharply from 12.9% in 1984 to 24.3% in 1985. However, after this period growth of the manufacturing sector stabilized falling to 11% and 10% in 1986 and 1987, respectively.

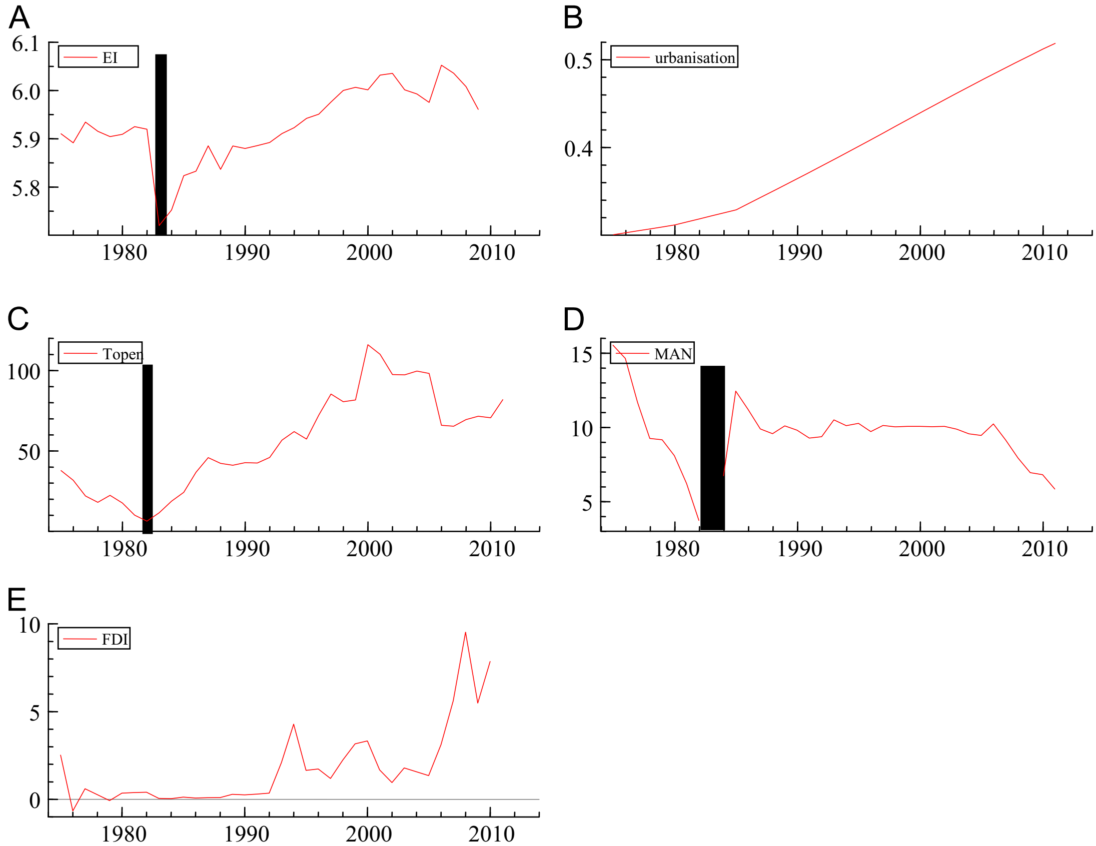

Fig. 1. Time series plot of variables.

As shown in Fig. 1D the sector's contribution to gross domestic product tempered off after the period 1985 but began to fall again after 2008. The changing technological characteristics of the sector imply that the effect of manufacturing output on energy intensity will depend on the technical disposition of the sector.

Prior to the reform, the increase in urbanization was remarkably steady, and this is shown by the flatness of the time plot of urbanization in Fig. 1B. This was due to both low growth in total population and economic growth prior to the reform. Also, prior to the reform, agriculture business was exceedingly much lucrative and this discouraged rural–urban migration. However, with the changing growth structure away from the agriculture sector and the biasedness of economic growth towards the urban areas after the reform in 1983, the rate of rural–urban migration increased sharply. This is reflected in the steep rise nature of the time plot of urbanization after the reform. This implies that annually the rate of urbanization increased sharply in the country after the reform and there seems to be no hope for a downward trend in the foreseeing future. The consistent sharp increase in the rate of urbanization gives a general impression of how growth has been more biased towards the urban center in Ghana.

The time plot for foreign direct investment shows that the net foreign direct inflow into the country was low and stable for a greater part of the period prior to reform and also after the reform. The general trend in foreign direct investment from 1975 to 1992 is explained by the political instability nature of the economy which spurred investment panics and deterred prospective investors from investing their capital in the country. However, the political environment after 1992 stabilized with the introduction of democratic governance. In 1992, the first democratic president was elected. This reduced investment panic slightly and hence improved foreign direct investment marginally. As shown in Fig. 1E the net foreign direct inflow increased significantly but reversed to its downward trend the period after showing cyclical variation until 2004. The levels of foreign direct investment after 1992 remained above the levels prior to 1992, but were still low. Though the period after 1992 had experienced political stability corruption was still high which worsened the overall performance of the economy. Thus, during this period the low foreign direct investment was purely one of economic mis management. However, after 2004, the economy witnessed a significant increase in net foreign direct inflows. During this period the macroeconomic performance of the country had improved significantly due to institutions of programmes to mitigate poverty, combat corruption, stabilize the cedi, and boost investors' confidence in the economy.

The intensity of energy use depends on the structure of the economy. Prior to 1983 the agricultural sector was the main anchor of growth in the country. Given the less energy intensive nature of the sector, energy intensity in the economy prior to 1983 was largely driven by the industrial sector. As shown in Fig. 1A energy intensity prior to the reform was on the high side. However, between 1981 and 1983, the rate of energy utilization decreased, in part, due to the economic crises experienced within the period. The period after reform shows consistent increased energy utilization in the country. The changing trend in energy intensity was spurred by the general economic growth experienced after the reform.

4. Data and methodology

This section provides a discussion on the data type used, the source of the data, the measurement of the data, the model specification, and the econometric technique applied to estimate the empirical model's parameters.

4.1. Data description and source

This study uses time series data covering the period from 1975 to 2011. Specifically the authors considered the following variables for the study; energy intensity, manufacturing valued-added, trade openness, foreign direct investment, urbanization, changing trade structure, and changing technical characteristics of the manufacturing sector. The variables changing trade structure and changing technical characteristics of the manufacturing sector were constructed by the authors. A policy regime dummy variable was interacted with trade openness and manufacturing value-added variables to obtain the changing trade structure and changing technical characteristics of the manufacturing sector variables, respectively. Data on trade openness, manufacturing value-added, urbanization, foreign direct investment, and energy intensity were obtained from the World Bank Development Indicators database.

4.2. Methodology

Regressions involving non-stationary regressors produce spurious results. Let $y_t = (y_{1t}, y_{2t})$ be an m-dimensional I (1) process. Then the cointegrating system in its triangular form can be represented as

$$y_{1t} = \beta' y_{2t} + \varepsilon_{1t} \tag{1}$$

$$\Delta y_{2t} = \varepsilon_{2t} \tag{2}$$

where $\varepsilon_t = (\varepsilon_{1t}', \varepsilon_{2t}')$ is, in a general case, strictly stationary with zero mean and finite covariance matrix $\sum$. Where $\sum$ is not block diagonal and ε_t is weakly dependent, the OLS estimator of β' is not efficient albeit consistent [44]. Moreover, Phillip and Hansen [44] argue that OLS regression suffers from endogeneity of the non-stationary regressors and serially correlated errors of the regression. Phillip–Hansen [44], Park [45], and Stock and Watson [46] have proposed different ways for dealing with the second-order bias problem.

The Fully-Modified OLS, by Phillip and Hansen [44], is a semi-parametric estimate, which is more robust to non-stationary regressors, serial correlation, and endogeneity. The FM-OLS first modifies the variables and then estimates directly to eliminate the existing nuisance parameters. The fully-modified OLS estimator is as given in Eq. (3).

$$\hat{\theta}_{FME} = \left(\sum_{t=1}^{T} z_t z_t'\right)^{-1} \left(\sum_{t=1}^{T} z_t y_t^{+} - T\hat{J}^{+}\right) \tag{3}$$

where $y_t^{+} = y_t - \hat{\lambda}_{ox}\hat{\lambda}_{xx}^{-1}\Delta x_t$ is the correction term for endogeneity, $\hat{\lambda}_{ox}$ and $\hat{\lambda}_{xx}$ are the kernel estimates of the long-run covariances, $\hat{J}^{+} = \hat{\Delta}_{ox} - \hat{\lambda}_{ox}\hat{\lambda}_{xx}^{-1}\hat{\Delta}_{xx}$ is the correction term for serial correlation, $\hat{\Delta}_{ox}$ and $\hat{\Delta}_{xx}$ are the kernel estimates of the one-sided long-run covariances.

The approach by Park [45], that is canonical cointegration, is similar to the FM-OLS. The point of departure, however, is that whilst the FM-OLS uses the transformations of both the data and estimates the CCR uses only the data transformation and selects a canonical regression among the class of models representing the same cointegrating relationship [45]. The CCR estimator is as shown in Eq. (4)

$$\hat{\theta}_{CCR} = \left(\sum_{t=1}^{T} Z_t^* Z_t^{*1}\right)^{-1} \sum_{t=1}^{T} Z_t^* Y_t^* \tag{4}$$

where $Y_t^* = (X_t^{*1}, D_t')$, $X_t^* = X_t - (\hat{\Sigma}^{-1}\hat{\wedge}_2)\hat{\nu}_t$, and $Y_t^* = Y_t - (\hat{\Sigma}^{-1}\hat{\wedge}_2\hat{\beta} + [\hat{\eta}_{22}^{-1}\hat{\omega}_{21}])'\hat{\nu}_t$ denotes the transformed data, $\hat{\beta}$ is an estimate of the cointegrating equation coefficients, $\hat{\wedge}_2$ is the second column of $\hat{\wedge}$ and $\hat{\Sigma}$ denotes estimated contemporaneous covariance matrix of the residuals.

Lastly the approach by Stock–Watson [46] (i.e. Dynamic OLS) eliminates the second-order bias problem by introducing leads and lags into the cointegrating equation. The rationale for the introduction of the leads and lags is to make the stochastic error term of the cointegrating equation independent of all past innovations in stochastic regressors. The model proposed by Stock–Watson is as given in Eq. (5)

$$Y_t = X_t'\beta + D_{1t}'Y_t + \sum_{j=-q}^{r} \Delta X_{t+j}'\delta + \nu_{1t} \tag{5}$$

The resulting estimator $\hat{\theta}_{DOLS} = (\hat{\beta}', \hat{\gamma}')'$ displays the same asymptotic distribution as those derived in the FMOLS and CCR. Asymptotically these three cointegrating regressions are known to be equivalent. In this study, estimates of the parameters of the empirical model are based on Phillip–Hansen, Park and Stock–Watson approaches.

Following from the literature, energy intensity is influenced by various factors prominent among them are structural change, energy price, urbanization, foreign direct investment, industrialization, and urbanization. Various empirical structures have evolved in the literature. For instance, Mielnik and Goldenberg [32] estimated a univariate model in which the effect of only foreign direct investment was assessed. The problem with univariate models is the omission of other important covariates that may be correlated with foreign direct investment. Also, Mielnik and Goldenberg [32] estimate of the univariate model using OLS raises concern as OLS regression of non-stationary series produce spurious result and a suspect of endogeneity and serial correlation problems. Studies such as Shen [36], Hubler and Keller [20], Eskeland and Harrison [30] and Fisher-Vabdeb et al. [12] estimated multivariate models which were an improvement over that estimated by Mielnik and Goldenberg [32]. However, these models are also either a suspect of multicolinearity problem or autocorrelation problem.

In this study, the authors adopt a multivariate empirical model in which the traditional variables such as urbanization, foreign direct investment, trade openness, and manufacturing value-added are included. As a novelty, the authors augment the current empirical model with two other important determinants of energy intensity; changing trade structure and changing technical characteristics of the manufacturing sector. The empirical model adopted in this study is as expressed in Eq. (6).

$$\ln ei_t = \alpha + \beta_1 man_t + \beta_2 Dman_t + \phi_1 Top_t + \phi_2 DTop_t + \gamma FDI_t + \lambda Urban_t + \varepsilon_t \tag{6}$$

where ln*ei* is the natural log transformation of energy intensity; man is manufacturing output; *Dman* is the interactive term for manufacturing, which captures the changing technical characteristics of the manufacturing sector; *Top* is trade openness; *DTop* is the interactive term for trade openness, which also captures the changing structure of trade in Ghana; *FDI* is foreign direct investment, and urban is the degree of urbanization.

Trade openness is the sum of exports and imports of goods and services measured as a share of gross domestic product [42]. This variable is an indication variable for the degree of economic openness of a country.

Manufacturing refers to industries belonging to ISIC divisions 15–37. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. Manufacturing value added as a percent of GDP is measured as manufacturing value added as a share of GDP [42]. In the literature, it is established that expansion in the scale of manufacturing output

increases energy intensity due to the energy intensive nature of the sector's activities or operations

Urban population refers to people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects. Urbanization is measured as urban population as a share of the total population [42]. The degree of urbanization in an economy is a surrogate measure of how economic growth has been biased towards the urban center. The effect of urbanization on energy intensity is established to be positive in the literature.

Foreign direct investment is net inflows of investment to acquire a lasting interest in or management control over an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvested earnings, other long-term capital, and short-term capital as shown in the balance of payments. This is measured as the net inflow of FDI as a percentage of GDP [42]. Generally the effect of foreign direct investment on energy intensity has been established to be negative. Nonetheless, other studies have found the effect of foreign direct investment to be positive.

Energy use per PPP GDP is the kilogram of oil equivalent of energy use per constant PPP GDP. Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport. PPP GDP is gross domestic product converted to 2005 constant international dollars using purchasing power parity rates [42]. Energy intensity is measured as the ratio of total energy consumption to gross domestic product.

The variables changing trade structure and changing technical characteristics of the manufacturing sector were constructed by the authors. A binary dummy for policy regime change was constructed in which the period before the reform in 1983 took 0 and the period after the reform took 1. This dummy was then interacted with the trade openness and manufacturing value-added variables to generate the changing trade structure and changing technical characteristics of the manufacturing sector variables, respectively. The drive for industrialization after the reform spurred investment in technology and institution of policies to abolish the importation of inefficient energy technologies into the country. This implies that the technical characteristics of the manufacturing sector after the reform improved in terms of application of more energy efficient technologies. As a result, the sign of the interactive dummy for manufacturing output is expected to be negative. On the contrary, the period after the reform saw much optimism for the export sector relative to the import sector. Thus, energy consumption via export increased relative to energy saving through import. As a result, the expected sign for the interactive trade openness variable is expected to be positive.

The important distinction between the empirical model adopted in this study and those adopted in other previous studies is that first the current empirical model captures the effects of changing structure of trade and changing technical characteristics of the manufacturing sector more explicitly. Secondly, the current empirical model is estimated by econometric techniques that are more robust to serial correlation and endogeneity problems.

5. Empirical results and discussion

This section provides a discussion on basic preliminary econometric description of variables (i.e. unit root test, unit root with structural break test, and cointegration test) and the result of the estimated empirical model. Also, a discussion on the relative importance of each regressor based on the Cholesky decomposition analysis is provided.

Table 1
Phillip–Perron unit root test.

Variables	Intercept	Intercept and trend
Fdi	−1.133015	−3.0974
D(fdi)	−8.5310*	−13.02935*
Man	−2.30618	−2.06235
D(man)	−6.69775*	−7.4974*
Topen	−0.891851	−2.14228
D(topen)	−5.13864*	−5.0599*
Urban	−1.4965	−1.6584
D(urban)	−3.2153**	−3.2709**
Lnei	−1.62289	−2.4476
D(lnei)	−6.74267*	−6.5668*

* Indicates 1% significance.
** Indicates 5% significance.

5.1. Unit root test result

Traditional ordinary least squares assume that series do not have memories of the past. However, time series variables have been known to possess memory of the past. When this happens, the moment conditions assumed under the traditional ordinary least square regressions are violated. Consequently, OLS regression involving such non-stationary series will produce spurious result. In such instances, cointegration analysis becomes appropriate. This implies that the test for unit root is a requirement for cointegration analysis.

In this study, the authors apply the Phillip–Perron test to test for unit root in series assuming both intercept and intercept with trend. The result is as shown in Table 1. The test of unit root using the level variables for the model with intercept reveals that the levels of all series are not stationary. Thus, energy intensity, foreign direct investment, manufacturing value-added, urbanization, and trade openness have unit root. This result is robust to the model with intercept and trend. The implication for this result is that the moment conditions are violated. Hence OLS regression involving these non-stationary series will produce a spurious result. In order to achieve stationarity, the series were differenced once, and the unit root test was further applied on the difference series. The result, as shown in Table 1 for the model with constant, shows that the series in their first differences are stationary. Thus, there is no unit root in energy intensity, urbanization, manufacturing value-added, trade openness, and foreign direct investment. This result is also robust to the model with constant and trend. This implies that the selected series are integrated of order one an indication that the moment conditions are satisfied at first difference.

5.2. Unit root test with structural break

Perron [47] argued that failure to allow for an existing break leads to a bias that reduces the ability to reject a false unit root null hypothesis. Thus, unit root test that allows for a structural break yields a test result which is biased towards non-rejection. The Zivot–Andrews test [48] is applied, in this study, to check for unit root with structural break. Three different types of breaks are considered. First is the crash model, which allows for a break in the intercept. Second is the changing growth model, which allows for a break in the slope or the rate of growth. Last is the combined crash and changing growth model, which allows for a break both in intercept and trend. The test is based on the null hypothesis of unit root with structural break against the alternative hypothesis of unit root with no structural break. The result is as shown in Table 2. The result indicates that, the null hypothesis of unit root with structural break cannot be rejected for energy intensity under the changing growth and combined growth models. However,

under the crash model, at 10% significance level, the null hypothesis of unit root with structural break cannot be accepted.

The null hypothesis of unit root with structural break cannot be rejected for the manufacturing series, and this is robust to all models. The test result further shows that for the trade openness and degree of urbanization variables, the null hypothesis of unit root with structural break cannot be accepted, and this result is robust to all models. Lastly, the test on foreign direct investment indicates that the null hypothesis cannot be accepted under the changing growth and combined models. However, under the crash model the null hypothesis cannot be rejected.

5.3. Test for long run equilibrium

The unit root test reveals that the series are difference stationary. Cointegration implies that albeit series may be non-stationary the linear combination among series is stationary. In this study, the authors proceed to test for cointegration using both test statistics of no cointegration [49,50] and test statistics of cointegration [51]. As argued in Shin [52], the limiting distribution of the test statistic for no cointegration depends only on a functional of Brownian motion and contains spurious regression distribution. However, the limiting distribution of the test statistics for cointegration involves a combination of a Brownian bridge and a functional of Brownian motion and depends on the compound normal distribution [53].

Based on the tau-statistic the Engle–Granger and Phillips–Ouliaris tests fail to reject the null hypothesis of no cointegration (see Table 3). This implies that FDI, manufacturing, trade openness and urbanization cannot be treated as the long run 'forcing' variables explaining energy intensity in Ghana. However, the result based on the Z-statistics are mixed. Whilst the Engle–Granger test confirms the existence of cointegration relation, the Phillips–Ouliaris confirms the existence of no cointegration. This inconclusiveness in the cointegrating result is dealt with using Hansen's cointegration test. The test result of the Hansen's technique reveals the existence of cointegration relationship. Thus, FDI, manufacturing output, urbanization and trade openness can be treated as the long run 'forcing' variables explaining energy intensity in Ghana.

Table 2
Zivot–Andrews unit root test with structural break.

Variable	Crash model	Changing growth model	Combined model
Fdi	−3.9507(2005)	−5.3903* (2005)	−5.5186** (2002)
Lnei	−4.6802*** (1983)	−3.7336 (1984)	−4.7492 (1983)
Man	0.3733 (2005)	0.4436 (2004)	−0.36184 (2005)
Topen	−5.5561* (2006)	−4.2022*** (2001)	−5.5199**(2000)
Urban	−4.8377*** (1986)	−5.5031*(1985)	−5.0448***(1984)

** Indicates 5% significance level.
* Indicates 1% significance level.
*** Indicates 10% significance level.

Table 3
Test for cointegration.

Cointegration test	Statistics Prob.	Prob.		Prob.	Null hypothesis
	Tau-statistics		Z-statistics		
Engle–Granger	−4.381	0.43	−52.069	0.000	No cointegration
Phillips–Ouliaris	−4.951	0.23	−25.496	0.362	No cointegration
Hansen's test	Lc statistics 0.348	Prob. 0.2			Cointegration

Table 4
Long-run Estimate.

Dependent Variable Ln (energy intensity) *Regressors*	FM-OLS *Coefficient*	Canonical cointegration *Coefficient*	Dynamic OLS *Coefficient*
Manufacturing	0.032** (0.0107)	0.039** (0.0184)	0.0267** (0.0120)
Trade openness	−0.0117** (0.0046)	−0.0151*** (0.0078)	−0.0088*** (0.0048)
Urbanization	0.6262** (0.1972)	0.47322*** (0.2660)	0.7485** (0.2476)
Foreign direct investment	0.0006 (0.0034)	0.0022 (0.0042)	0.0008 (0.0041)
Interactive manufacturing variable	-0.0372* (0.0096)	-0.0460** (0.0176)	0.0267** (0.0104)
Interactive trade openness variable	0.0131* (0.0046)	0.01673** (0.0077)	0.0099*** (0.0048)
Constant	5.6404* (0.0710)	5.6984* (0.0952)	5.5969* (0.0883)
R-squared	0.799	0.7726	0.80567
Adjusted R-squared	0.751	0.71805	0.7625
Long-run variance	**0.000549**	**0.000549**	**0.000907**

* Indicates 1% significance level.
** Indicates 5% significance level.
*** Indicates 10% significance level. values in parenthesis indicate standard errors.

5.4. Long run analysis

The authors proceed to analyze the long run impact of FDI, trade openness, manufacturing output, changing trade structure, changing technical characteristics of the manufacturing sector and urbanization on Ghana's energy intensity (see Table 4). The long run impact of manufacturing output is positive and significant at the 5% significance level. This result is robust in all three regression models. In all three models, the coefficient implies that a 1% expansion of the manufacturing sector will increase Ghana's energy intensity by approximately 3%. Activities of the manufacturing sector are highly energy driven, which implies that further expansion in the scale of manufacturing activities in Ghana will spur energy demand pressures. Consequently energy intensity increases. However, changing production mix of the manufacturing sector and changing technical characteristics of the manufacturing sector can produce desirable outcomes in terms of the country's energy efficiency.

In order to capture the impact of the changing technical characteristics of the manufacturing sector on energy intensity in Ghana after the reform, an interactive manufacturing output variable is included as an additional regressor. The estimated coefficient is negative, statistically significant and asymptotically equivalent in all three models. The estimated coefficient suggests that after the reform in 1983, for every 1% expansion in the scale of the manufacturing sector energy intensity reduces by 3% approximately. The changing manufacturing output effect is an evidence of the impact of policy regime changes on estimated parameters. Policy regime changes result in changing structure of the economy. In the case of Ghana, there was a structural shift in the manufacturing sector after the reform in 1983. First product mix changed from highly energy intensive products to less energy intensive products. Also, trade reforms after the reform promoted technological transfer in the manufacturing sector, which improved product quality and efficiency. Lastly, policies that banned the importation of

technological inefficient machineries after the reform ensured that only energy efficient machineries and equipments were used in the manufacturing sector of Ghana. The result suggests that changing trends in technological innovation within the manufacturing sector, policies of energy conservation and efficiency and changing production mix in the manufacturing sector have had desirable consequences on the country's energy saving.

The long run impact of trade openness on energy intensity is negative and statistically significant. The result is robust in all three regression models. The estimated coefficient shows that for every 1% expansion in trade openness the economy-wide energy intensity reduces by 1.2% approximately. This implies that as the degree of economic integration intensifies the rate of energy usage reduces. Integration of economies into the world economy facilitates the transfer of equipments and machinery, which have technology embedded in them. Also, integration of economies spurs competition, which compels local firms to adopt efficient technologies to make them competitive. Thus, trade openness reduces energy intensity via the learning and demonstration effects.

The structure of trade changed after the reform in 1983. The coefficient for the interaction of the dummy for reform and trade openness is positive and statistically significant. The result is robust in all three regression models. The estimated coefficient implies that a 1% increase in trade after the reform in 1983 leads to a 1.3%, 1.7% and 1% increase in energy intensity in the FMOLS, CCR, and DMOLS models, respectively. This implies that after the reform energy intensity increased because the energy saving through imports is less than energy consuming through exports. As argued by Fisher-Vabdeb et al. [12], the impact of trade on energy efficiency depends on whether the country imports energy intensive or export energy intensive. This result is in contrast with Shen [36].

The impact of urbanization on energy intensity is positive and statistically significant. This result is robust in all three regressions. This result confirms Sadorsky [41]. The estimated coefficients imply that a 1% increase in the rate of urbanization leads to a 63%, 47%, and 75% increase in energy intensity in the FMOLS, CCR, and DOLS regressions, respectively. The urban centers get easily connected to the national grid. Also, urbanization spurs industrialization. This implies that as the degree of urbanization intensifies the rate of energy usage increases through the industrialization process and increased use of energy-using appliances. In Ghana, industrialization is centered in the urban centers. This increases employment opportunities in the urban centers and thus, leads to increases in incomes of the urban population. The increase in urban population incomes spur demand for energy-using appliances and hence increase the rate of energy usage in the urban centers. The impact of foreign direct investment is positive and statistically not significant. This result is robust in all three regression outputs. This implies that technological diffusion via trade exerts significant influence on energy intensity than technological diffusion via foreign direct investment in Ghana.

5.5. Variance decomposition analysis

Lastly the authors apply a decomposition method to delineate the actual contribution of manufacturing output, foreign direct investment, trade openness, and urbanization in explaining energy intensity in Ghana. Thus, using the Cholesky decomposition, the authors estimate what percentage of every one standard deviation shock in energy intensity is accounted for by manufacturing output, trade openness, urbanization and foreign direct investment. The result is as shown in Table 5. The result indicates that, for every one standard deviation shock, the contribution of all factors increases with time. For instance, the contribution of the manufacturing sector increases from 0.66% in the second period to 19.24% in the tenth period. Likewise, the contribution of foreign direct investment increases steadily from 4.3% in the second period to 6.76% in the tenth year. Also, the contribution of urbanization to energy intensity changes in the country increases sharply from 0.07% in the second period to 10.52% in the tenth period. The contribution of trade to future changes in energy intensity in Ghana is, however, radical changing from 1.81% in the second period to 26.43% in the tenth year. In all, trade openness contributes largely to changing future energy intensity in the country followed by manufacturing output. The contributions of urbanization and foreign direct investment to future changes in energy intensity in the country are moderate.

Table 5
Cholesky decomposition analysis.

TH	S.E.	LNEEI	MAN	FDI	TOPEN	URBAN
1	0.026530	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.028940	93.16577	0.658432	4.295991	1.807765	0.072045
3	0.031050	87.24227	1.388965	4.906555	6.398172	0.064038
4	0.034048	77.92053	4.989999	5.163899	11.55429	0.371278
5	0.037784	70.26759	9.885882	5.084732	13.21867	1.543125
6	0.041095	63.34236	13.27624	5.479594	14.86822	3.033596
7	0.044247	55.79081	15.37289	6.174196	18.09810	4.564002
8	0.047777	48.29711	16.96382	6.607353	21.84784	6.283868
9	0.051532	41.97615	18.34910	6.722923	24.62561	8.326222
10	0.055171	37.05882	19.23643	6.755244	26.43393	10.51557

Cholesky ordering: lnei man fdi topen urban.

6. Conclusion and recommendations

The study examined the impact of changing trade structure and changing technical characteristics of the manufacturing sector, alongside the effects of urbanization and foreign direct investment on energy intensity in Ghana using time series data from 1975 to 2011. The study employed FMOLS, CCR, and DOLS models which are more robust to the second-order bias problem. The Preliminary findings on cointegration based on the test statistics of no cointegration (i.e. Engle–Granger and Phillip–Ouliaris test) produced mixed results. However, the test by Hansen indicated the existence of cointegration. Thus, foreign direct investment, manufacturing output, urbanization, and trade openness can be treated as the “long run forcing” variables explaining energy intensity.

The long run analysis based on Canonical cointegration, dynamic OLS, and fully modified OLS indicates that increasing urbanization and scale of manufacturing output increase energy intensity significantly. The impact of foreign direct investment on energy intensity is positive but statistically not significant. Increasing trade openness, however, reduces energy intensity significantly in Ghana. In order to capture the changing technical structure of the manufacturing sector and trade after the reform two interactive variables were introduced as additional regressors of the model. The coefficient for the interactive trade variable is positive and statistically significant. This result is robust in all three regression models. This implies that increasing trade openness increased energy intensity after the reform. This is because, after the reform, the energy consumed via exports outweighed the energy saved via imports. The coefficient for the interactive term for manufacturing output is, however, negative an indication that after the reform increasing manufacturing scale increased energy efficiency in the country. This is because the production mix of the manufacturing sector changed from more energy intensive to less energy intensive. Also, the period experienced the promotion of importation of highly energy efficient technologies via the implementation of energy efficiency standards in the country. In all,

technological diffusion via trade has an important effect on energy intensity than technological diffusion via foreign direct investment.

The implications of the study are that a change in the production mix in favor of less energy intensive products and changing technical characteristics of the manufacturing sector, which are biased towards energy efficient technologies, reduce energy intensity. However, export of more energy intensive products increases energy intensity. Also, the result of the study implies that, increasing urbanization spur energy demand pressures, which increases energy intensity in the country. This suggests that policies aimed at encouraging the production of less energy intensive products and implementation of high energy efficient technologies in the manufacturing sector should be promoted. Encouraging exportation of less energy intensive products and importation of highly energy efficient technologies can also help reduce energy intensity in the country. Lastly, efforts to decentralize growth in the country can reduce pressures in the urban areas and hence reduce urbanization and energy intensity.

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